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Effect of Post-Harvest Degreening on Quality Parameters of Acid Lime Cv. Balaji

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Authors' contributions

This work was carried out in collaboration between both authors. Author PY designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author KKA managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Analyze the effect of post-harvest degreening on quality parameters of Acid lime cv. Balaji. The present research was conducted at Post harvest laboratory of College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, during the year 2018-2019. Experiment was designated with two factorial completely randomized design with two factors viz., (A) Ethylene concentrations, (B) Number of pulsings were taken for test and executed with the objective: Effect of post-harvest degreening on quality parameters of Acid lime cv. Balaji. The Acid lime cv. Balaji fruits were harvested and subjected to degreening treatments for one day. The treated Acid lime fruits were stored for sixteen days at ambient conditions. Acid lime fruits picked randomly from treated lot and evaluated for Physiological loss in weight %, Peel thickness mm, Fruit firmness Kg/cm^2, Total soluble solids °Bx, Titratable acidity %, Ascorbic acid mg/100 g, Juice recovery % at four days interval by adopting the respective methods. Among all the quality parameters there were gradual increase in Total soluble solids (TSS), Juice recovery, Physiological

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loss in weight (PLW) and there were decreased trend in Titratable acidity, Peel thickness, Fruit firmness and Ascorbic acid content. Ethylene @ 15 ppm proved the better results for the above parameters. Among different number of pulsings, 1 pulsing in 24 hours @ 24 hrs interval and 2 pulsings in 24 hr @ 12 hrs interval was best.

Keywords: Degreening; acid lime; cv. Balaji; ethylene.

1. INTRODUCTION

Acid lime cv. Balaji (*Citrus aurantifolia* S.) is a subtropical in its climacteric requirements and originated from subtropical South-east Asia, which belongs to family Rutaceae. It is an important fruit crop in citrus group. India is the largest producers of Acid lime cv. Balaji in the world followed by USA, Spain and Israel. Bacterial canker is a major disease in Acid lime. The Acid lime cv. Balaji developed at All India Co-ordinated Research Project on Citrus, Sri Venkateshwara Agricultural College, Tirupati was a hybrid and is resistant to the disease. Among the different cultivars of Acid lime, Balaji is the important cultivated variety in Telangana and has resistant to canker. Consumers prefer bright colored citrus fruit and are willing to pay a premium for them. Green colored fruits are considered unripe and fetch lower prices. Hence the color of the rind is important for the aesthetic value and as such it is the most important factor determining marketability. Despite citrus being a non-climacteric fruit, some aspects of its ripening is still sensitive to external exposure to ethylene [1]. Degreening is the process of degradation of chlorophyll by ethylene, where luxuriant growing conditions cause chlorophyll to persist or reappear in the rinds of mature fruit [2].

2. MATERIALS AND METHODS

2.1 Experimental Materials

2.1.1 Acid lime cv. balaji fruits

Acid lime cv. Balaji (*Citrus aurantifolia* S.) fruits were collected from citrus orchard. Matured fruits are harvested manually and immediately transported to degreening chamber and subjected to the ethylene treatments at room temperature 27-28°C. Treated fruits were stored up to 16 days. Some treatments were spoiled after 12 days of storage. Their mean values were recorded.

2.1.2 Ethylene cylinder

Ethylene release canisters named Ripylene, manufactured by Chemtron science laboratories, Mumbai were used in the research. 15 grams of ethylene gas was filled in a cylinder with adjustable gauge. This was approved by National Horticulture Board, Food Safety and Standards Authority of India and Food and Drug Administration as a gas for ripening.

2.1.3 Low-cost ripening chamber

The low-cost ripening chamber consists of 40 mm PUF (Polyurethane Foam) insulated panels with PPGI Sheets (Pre painted Galvanised Iron) lamination on either side, with flashings and swing door - 300 x 600 mm with the capacity of 5 crates (100 kg).

2.1.4 Ethylene treatment

The fruits of Acid lime (*Citrus aurantifolia* S.) cv. Balaji were treated with 5 ppm, 10 ppm, 15 ppm and 20 ppm of ethylene. Ethylene gas as per the required concentration was released in to the low-cost ripening chamber as detailed bellow. In low cost ripening chamber standardisation of ethylene gas for different concentrations (5 ppm, 10 ppm, 15 ppm and 20 ppm) was carried out on the basis of bubble count (20 bubbles per 10 sec) using ethylene sensor at Post harvest laboratory of College of Horticulture, Sri Konda Laxman Telangana State Horticultural University.

Table 1. Standardisation of ethylene dose for degreening of acid lime (*Citrus aurantifolia* S.) cv. balaji in low cost ripening chamber

Ethylene dose	No. of bubbles/10 sec	Time of ethylene gas to be released
5ppm	20	1 min.
10ppm	20	1.30 sec.
15ppm	20	1.45 sec.
20ppm	20	2 min.

2.1.5 Experimental details

In the experiment, two factors *viz.,* (A) Ethylene concentrations, (B) Number of pulsings were taken for test. Acid lime cv. Balaji fruits were allowed to degreen in Low Cost Ripening Chamber with ethylene treatment with different levels of ethylene concentrations *i.e.* (A_1) 5 ppm (A_2) 10 ppm (A_3) 15 ppm and (A_4) 20 ppm were given four levels of number of pulsing *viz.*, (B_1) 6 pulsings in 24 hrs @ 4 hrs interval (B_2) 4 pulsings in 24 hrs @ 6 hrs interval (B_3) 2 pulsings in 24 hrs @ 12 hrs interval and (B_4) 1 pulsing in 24 hrs @ 24 hrs interval. The combination of 2 factors gives 16 treatments *viz.,*

T_1. 5 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval
T_2. 5 ppm ethylene with 4 pulsings in 24 hrs @ 6 hrs interval
T_3. 5 ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval
T_4. 5 ppm ethylenewith 1 pulsing in 24 hrs @ 24 hrs interval
T_5. 10 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval
T_6. 10 ppm ethylene with 4 pulsings in 24 hrs @ 6 hrs interval
T_7. 10 ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval
T_8. 10 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval
T_9. 15 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval
T_{10}. 15 ppm ethylene with 4 pulsings in 24 hrs @ 6 hrs interval
T_{11}. 15 ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval
T_{12}. 15 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval
T_{13}. 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval
T_{14}. 20 ppm ethylene with 4 pulsings in 24 hrs @ 6 hrs interval
T_{15}. 20 ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval
T_{16}. 20 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval

Table 2. Acid lime cv. balaji fruits after harvest without subjecting to ethylene (Control)

Name of the Parameter	1st day	4th day	8th day
PLW (%)	-	8.83	15.88
Peel thickness (mm)	1.71	1.68	0.96
Firmness ($Kg/cm^{2)}$	8.22	8.16	7.72
TSS (ºBx)	6.34	6.44	6.62
Titrable Acidity (%)	8.31	8.18	7.75
Ascorbic Acid (mg/100 g)	49.99	49.92	42.88
Juice Recovery (%)	30.88	35.42	31.18

2.2 Methodology

2.2.1 Physiological loss in weight (%)

The initial weight of the fruits was recorded on electric top pan balance in each treatment. Thereafter the weight of fruits under each treatment was recorded at four days interval during storage. At regular intervals cumulative loss in weight was calculated and expressed as percent physiological loss in weight (%).

PLW is calculated as shown in the Equation 1.

$$PLW = \frac{Initial\ weight - Final\ Weight}{Initial\ weight} \times 100$$

2.2.2 Peel thickness (mm)

The peel thickness from each replication was measured with the help of digital Vernier callipers and average values were computed. The peel was removed, a piece was placed between the two measuring jaws and reading was taken in millimeters.

2.2.3 Fruit firmness (kg/cm^2)

Fruit firmness at random was measured on ten fruits from each treatment by measuring the penetration force with penetrometer (Fruit pressure tester method. FT 327) equipped with a probe of 8.0 mm diameter and expressed in kg/cm^2.

2.2.4 Total soluble solids (°bx)

Total soluble solid of ripe fruit pulp were recorded by digital refractometer (ranging from 0-32 °Bx). Drop of extracted Acid lime fruit juice was put on digital refractometer and reading was recorded and expressed in terms of degree brix. Ten readings were taken for each treatment and finally their average value was worked out.

2.2.5 Titratable acidity (%)

Method described by Ranganna [3] was adopted for estimation of titratable acidity. To obtain acidity (per cent), 10 g of homogenized juice was taken in a 100 ml volumetric flask and the volume was made. The suspension was filtered through Whatman No. 1 filter paper 10 ml of the filtrate was taken by pipeting and titrated against 0.1 N NaOH. Phenolphthalein was used as an indicator. Appearance of colourless to pink colour denotes the end point. The reading of burette was noted. The per cent acidity was calculated by using the equation 2.

$$Titratable\ Acidity\ (\%) = \frac{Titre\ Value\ \times Normality\ of\ NaOH\ \times Volume\ Made\ Up\ \times Equivalent\ Wt.of\ Citric\ Acid\ \times 100}{Volume\ of\ Sample\ Taken\ for\ Estimation\ \times Weight\ of\ Sample\ \times 1000}$$

2.2.6 Ascorbic acid (mg/100 g)

Ascorbic acid was estimated by the procedure elicited by Ranganna [4]. Ten grams of fruit tissue was blended in 3% meta-phosphoric acid and the volume was made up to 100 ml of H_3PO_4. The contents were filtered through Whatman No.1 filter paper and 10 ml of the aliquot was taken and titrated with standard dye (2, 6-dichlorophenol-indophenol dye) to a pink end point. The ascorbic acid was expressed as mg ascorbic acid/100 g. Ascorbic acid was calculated by using the equation 3.

$$Ascorbic\ Acid := \frac{Titre\ Value\ \times Dye\ Factor\ \times Volume\ Made\ Up\ \times 100}{Aliquot\ Taken\ for\ Estimation\ \times Weight\ of\ Sample\ for\ Estimation}$$

2.2.7Juice recovery (%)

The juice was extracted from the sample fruits with the help of juice extractor and strained through single mesh filter to remove rag, seeds and left-over waste. The average weight of the fruits per replication, strained juice was weighed and percentage of juice content per fruit was worked for each replication at regular intervals. Juice recovery is calculated as shown in the equation 4.

$$Juice\ (\%) = \frac{Weight\ of\ the\ juice\ (g)}{Weight\ of\ the\ fruit\ from\ which\ juice\ was\ taken\ (g)} \times 100$$

2.2.8 Statistical analysis

The design adopted was completely randomized design with 2 factors (ethylene dose and number of pulsings). All the analysis was performed in 3 replicates of samples and the results were presented as critical difference (CD) and standard deviation. The experimental data were subjected to (ANOVA) using module of ICAR CCARI WASP. Least significance difference (Fisher’s protected LSD) were calculated following significant F test (p=0.05). All assumptions of analysis were checked to ensure validity.

3. RESULTS AND DISCUSSION

3.1 Physiological Loss in Weight

The data pertaining to physiological weight loss of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 3.

It is evident from the data that as the ripening advanced; physiological weight loss (%) increased progressively at ambient conditions and significantly differed among the treatments. Physiological weight loss is a continuous phenomenon during storage due to moisture loss. Moisture loss through respiration and transpiration during storage affects the salable weight and eventually the fruit becomes unsalable as a result of shrinking [5]. Hence, increase in weight loss during storage in the present study could be attributed to the aforesaid reason. Ladaniya and Singh [6] reported that, no difference due to ethylene treatment but cumulative weight loss was higher in non-degreened fruits. The loss in weight was less under control treatment as compared to ethephon treatments in initial days of storage indicating that the ripening process of the fruits was not started properly. But the loss was suddenly on higher side after 12 days of storage in control fruits.

On 4^{th} day among the ethylene concentrations, significantly highest weight loss was recorded with ethylene @ 20 ppm (9.73%) followed by ethylene @ 5 ppm (9.35%); while, lowest with 15 ppm (7.14%). Among the number of pulsing, significantly highest weight loss was recorded with 6 pulsings in 24 hrs @ 4 hrs interval (9.19%), followed by 4 pulsings in 24 hrs @ 6 hrs interval (8.97%); while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (8.13%). On 8^{th} day among the ethylene concentrations, significantly highest weight loss was recorded with 5 ppm (16.44%) followed by ethylene @ 20 ppm (15.29%); while, lowest with 15 ppm (12.22%). Among the number of pulsings, significantly highest weight loss was recorded with 6 pulsings in 24 hrs @ 4 hrs interval (15.61%), followed by 4 pulsings in 24 hrs @ 6 hrs interval (15.17%); while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (13.84%).

Among the storage days, 4^{th} and 8^{th} day interaction between ethylene concentrations and number of pulsings were significantly differed. On 4^{th} day significantly highest weight loss was recorded in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (10.44%); while, lowest with 15 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (6.43%). On 8^{th} day significantly highest weight loss was recorded in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (16.92%); while, lowest in 15 ppm ethylene with 2 pulsings in 24 hrs @ 12 hrs interval (11.62%). The mean values recorded in PLW of Acid lime cv. Balaji fruits at 12^{th} day and 16^{th} day during storage tabulated at Table 3. A similar decreasing trend in respect of PLW was observed. Similar increase in PLW of ethylene treated fruits was observed in pear earlier by Dhillon and Mahajan [7]. This could be due to increased metabolic activities under the influence of ethylene.

3.2 Peel Thickness (mm)

The data pertaining to Peel thickness (mm) of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 4. It is evident from the data that, as the storage days increased there was a decreasing trend in peel thickness of citrus [8]. Bananas ripened at higher temperatures (20°C) showed a significantly higher pulp/peel ratio than those ripened at low temperatures (16°C). Reason for the greater pulp/peel ratio at higher temperatures could be due to the greater weight loss. Because the pulp mass of banana fruit increases during ripening due to an increase in water content, it could be due to the movement of water from peel to pulp and to the surrounding air [9].

On 4^{th} day among the ethylene concentrations, significantly maximum peel thickness was noticed with ethylene @ 5 ppm (1.66 mm); while, minimum with 20 ppm (0.51 mm). Among the number of pulsings, results were non-significant. On 8^{th} day among the ethylene concentrations, significantly maximum peel thickness was noticed with ethylene @ 5 ppm (0.94 mm); while, minimum with 20 ppm (0.41 mm). Among the number of pulsings, significantly maximum peel thickness was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (0.71 mm). Among the number of pulsings, significantly maximum peel thickness was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (0.71 mm). 2 pulsings in 24 hrs @ 12 hrs interval (0.68 mm), 4 pulsings in 24 hrs @ 6 hrs interval (0.65 mm) and 6 pulsings in 24 hrs @ 4 hrs intervals (0.63 mm) were at par with 1 pulsing in 24 hrs @ 24 hrs interval (0.71 mm).

Table 3a. Physiological loss in weight (%) of acid lime cv. balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	9.72	9.58	9.26	8.81	8.64	8.52	8.35	8.23	7.95	7.54	6.65	6.43	10.44	10.25	9.18	9.04
8th day	16.81	16.60	16.52	15.83	15.63	15.51	13.54	13.47	13.07	11.74	11.62	12.44	16.92	16.84	13.75	13.62
12th day	-	-	-	-	25.79	24.80	-	-	20.06	16.27	16.46	19.86	-	-	-	-
16th day	-	-	-	-	-	-	-	-	-	24.43	24.66	-	-	-	-	-

Table 3b. Critical difference and standard error of physiological loss in weight (%) on 4th and 8th day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.04	0.01	0.04	0.02
Number of pulsings (B)	0.04	0.01	0.04	0.02
Factor A × B	0.08	0.02	0.09	0.03

Table 4a. Peel thickness (mm) of acid lime cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	1.63	1.64	1.67	1.69	0.93	0.94	0.95	0.97	0.63	0.65	0.67	0.69	0.46	0.47	0.54	0.57
8th day	0.92	0.93	0.94	0.95	0.72	0.76	0.81	0.88	0.52	0.53	0.54	0.55	0.36	0.37	0.44	0.46
12th day	-	-	-	-	0.68	0.72	-	-	0.49	0.50	0.51	0.52	-	-	0.40	0.41
16th day	-	-	-	-	-	-	-	-	-	0.46	0.48	-	-	-	-	-

Table 4b. Critical difference and standard error of peel thickness (mm) on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.07	0.02	0.04	0.01
Number of pulsings (B)	N. S	0.02	0.04	0.01
Factor A × B	N. S	0.05	N. S	0.03

Among storage days, 4th and 8th day interaction between ethylene concentration and number of pulsings were non-significant. The mean values recorded in the peel thickness of Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated in Table 4. A similar decreasing trend in respect of peel thickness was observed. Present results were agreement with Krishna and Sreenivasula [10] who reported that, orange peel tensile strength, modulus of elasticity and cutting energy decreased with storage period in both ambient and refrigerated conditions. Firmness, puncture force and cutting energy of orange fruits decreased with respect to number of days of storage.

3.3 Fruit Firmness (kg/cm^2)

The data pertaining to Fruit firmness (kg/cm^2) of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 5. It is evident from the data that as the ripening advanced, fruit firmness decreased progressively at ambient conditions and significantly differed among the treatments. It is observed from the data that, as the storage days increased there was a decreasing trend in fruit firmness of Citrus. Hayat et al. [11] stated that firmness of lime fruits was reduced with an increased storage. Ethylene encourages the fruit ripening can progress into physiological development and the flesh and fruit can become soft [12].

On 4th day among the ethylene concentrations, significantly maximum fruit firmness was noticed with ethylene @ 5 ppm (7.86 kg/cm^2); while, minimum with 20 ppm (6.39 kg/cm^2). Among the number of pulsings, significantly maximum fruit firmness was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (7.26 kg/cm^2); while, minimum with 6 pulsings in 24 hrs @ 4 hrs interval (6.94 kg/cm^2). On 8th day among the ethylene concentrations, significantly maximum fruit firmness was noticed with ethylene @ 5 ppm (7.50 kg/cm^2); while, minimum with 20 ppm (6.29 kg/cm^2). Among the number of pulsings, significantly maximum fruit firmness was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (7.01 kg/cm^2); while, minimum with 6 pulsings in 24 hrs @ 4 hrs interval (6.69 kg/cm^2).

Among the interaction studies non-significant results were noticed with 4th and 8th days. The mean values recorded in the fruit firmness (kg/cm^2) of Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated in Table 5. A similar decreasing trend in respect of fruit firmness (kg/cm^2) was observed. Similar results were observed in pear by Dhillon and Mahajan [7]. As the ripening process increases firmness of the fruit decreases. Dissolution of pectin polysaccharides was responsible for decreasing the fruit firmness.

3.4 Total Soluble Solids (°Bx)

The data pertaining to TSS °Bx of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 6. It is observed from the data that, as the storage days increased there was an increasing trend in TSS of citrus. According to Hayat et al. [11] TSS of lime fruits was increased progressively with an increase in storage period. It may be due to continues process of respiration and transpiration has resulted in weight loss and conversion of starch to sugars by the activity of hydrolytic enzymes [7].

On 4th day among the ethylene concentrations, significantly highest TSS was reported with 20 ppm (9.4 °Bx); while, lowest with 5 ppm (6.87 °Bx). Among the time of pulsing significantly highest TSS was reported with 6 pulsings in 24 hrs @ 4 hrs interval (8.63 °Bx); while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval (7.92 Brix°). On 8th day among the ethylene concentrations, significantly highest TSS was reported with 20 ppm (9.76 °Bx); while, lowest with 5 ppm (7.01 °Bx) Among the time of pulsing significantly highest TSS was reported with 6 pulsings in 24 hrs @ 4 hrs interval (8.92 °Bx); while, minimum with 1 pulsing in 24 hrs @ 24 hrs interval (8.23 °Bx).

Among the storage days 4th and 8th day interaction between ethylene concentration and number of pulsings were significantly differed. On 4th day significantly highest TSS was reported in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (9.71 °Bx); while, lowest in 5 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (6.48 °Bx). On 8th day significantly highest TSS was reported in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (10.22 °Bx) followed by 20 ppm ethylene with 4 pulsings in 24 hrs @ 6 hrs interval (9.80 °Bx); while, lowest in 5 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (6.77 °Bx). The mean values recorded in the TSS (°Bx) of Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated at Table 4. A similar increasing trend in respect of TSS (°Bx) was observed. Similar results were observed in Pear [7], Lime [13].

3.5 Titratable Acidity (%)

The data pertaining to Titratable acidity of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 7. It is evident from the data that, as the storage days increased there was a decreasing trend in titratable acidity of citrus. Decrease in acidity during prolonged storage has been reported by various workers in different fruits, such as in Lime [13]. This can be attributed due to the conversion of organic acids into soluble sugars and long chain polysaccharides may also lead to decrease in acid content.

On 4th day among the ethylene concentrations, significantly highest % of titratable acidity was noticed with ethylene @ 5 ppm (7.85%); while, lowest with 20 ppm (6.45%). Among the number of pulsings, significantly highest % of titratable acidity was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (7.42%); while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (6.84%). On 8th day among the ethylene concentrations, significantly highest % of titratable acidity was noticed with 5 ppm (7.41%); while, lowest with 20 ppm (6.09%). Among the number of pulsings, significantly highest % titratable acidity was noticed with 1 pulsing in 24 hrs @ 24 hrs interval (7.02%); while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (6.45%).

Among the storage days 4th and 8th day interaction between ethylene concentration and number of pulsings were non-significant. The mean values recorded in the titratable acidity of Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated in Table 7. A similar decreasing trend in respect of titratable acidity was observed. Degreening increased there was a decreasing trend in titratable acidity of citrus. This could be due to rapid utilization of organic acids in the respiratory process [14] and increased metabolic activities under the influence of ethylene [15].

3.6 Ascorbic Acid (mg/100 g)

The data pertaining to ascorbic acid (mg/100 g) of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 8. In present investigation, vitamin C content was decreased with an increase in storage time. Degreening process promotes the conversion of acids to sugars, leads to decrease in the ascorbic acid content [16]. With the advancement of storage period, total soluble solids were increased while ascorbic acid and acidity of fruits decreased in Kagzi lime [17].

On 4th day among the ethylene concentrations, significantly maximum level of ascorbic acid was recorded with ethylene @ 5 ppm (49.89 mg/100 g); while, lowest with 20 ppm (44.53 mg/100 g). Among the time of pulsing significantly maximum level of ascorbic acid was recorded with 1 pulsing in 24 hrs @ 24 hrs interval (47.59 mg/100 g); while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (46.55 mg/100 g). On 8th day among the ethylene concentrations, significantly maximum level of ascorbic acid was recorded with ethylene @ 5 ppm (42.50 mg/100 g); while, lowest with 20 ppm (38.69 mg/100 g). Among the time of pulsing significantly maximum level of ascorbic acid was recorded with 1 pulsing in 24 hrs @ 24 hrs interval (41.24 mg/100 g); while, lowest with 6 pulsings in 24 hrs @ 4 hrs interval (40.26 mg/100 g).

Among the storage days 4th and 8th day interaction between ethylene concentration and number of pulsings were significantly differed. On 4th day significantly maximum level of ascorbic acid was noticed in 5 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (49.98 mg/100 g); while, minimum in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (43.73 mg/100 g). On 8th day significantly maximum level of ascorbic acid was noticed in 5 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval (42.86 mg/100 g); while, lowest in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval (38.24 mg/100 g). The mean values recorded in the ascorbic acid of Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated in Table 8. A similar decreasing trend in respect of ascorbic acid was observed. Present results were agreement with some previous studies [18,16]. Where vitamin C content was slightly reduced during the storage. The decline in vitamin C content seems to be caused by the oxidation of ascorbic acid by enzymes.

Table 5a. Fruit firmness kg/cm^2 of acid lime cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	7.64	7.84	7.93	8.05	7.14	7.25	7.35	7.44	6.74	6.84	6.94	7.04	6.24	6.36	6.44	6.53
8th day	7.29	7.53	7.54	7.67	6.84	6.93	7.05	7.15	6.56	6.65	6.75	6.79	6.09	6.26	6.39	6.45
12th day	-	-	-	-	6.91	7.04	-	-	6.45	6.53	6.65	6.76	-	-	6.24	6.38
16th day	-	-	-	-	-	-	-	-	-	6.40	6.52	-	-	-	-	-

Table 5b. Critical difference and standard error on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.03	0.01	0.04	0.01
Number of pulsings (B)	0.03	0.01	0.04	0.01
Factor A × B	N. S	0.02	N. S	0.03

Table 6a. Total soluble solids (°Bx) of acid lime cv. Balaji as Influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	7.48	6.79	6.70	6.48	8.46	8.15	8.01	7.80	8.87	8.71	8.55	8.35	9.71	9.62	9.26	9.02
8th day	7.51	6.90	6.87	6.77	8.75	8.35	8.27	8.02	9.21	9.01	8.81	8.71	10.22	9.80	9.61	9.40
12th day	-	-	-	-	8.57	8.34	-	-	9.46	9.25	9.01	8.94	-	-	9.80	9.63
16th day	-	-	-	-	-	-	-	-	-	9.41	9.27	-	-	-	-	-

Table 6b. Critical difference and standard error of total soluble solids (°Bx) on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.09	0.03	0.06	0.02
Number of pulsings (B)	0.09	0.03	0.06	0.02
Factor A × B	0.17	0.06	0.11	0.04

Table 7a. Titratable acidity (%) of acid lime cv. balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	7.63	7.71	7.90	8.16	7.06	7.22	7.42	7.67	6.41	6.59	6.81	7.08	6.26	6.30	6.50	6.75
8th day	7.08	7.31	7.50	7.73	6.81	7.07	7.32	7.41	6.08	6.38	6.52	6.72	5.82	5.90	6.13	6.21
12th day	-	-	-	-	7.18	7.33	-	-	5.81	6.01	6.22	6.41	-	-	5.72	5.94
16th day	-	-	-	-	-	-	-	-	-	5.81	6.01	-	-	-	-	-

Table 7b. Critical difference and standard error of titratable acidity (%) on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.04	0.02	0.06	0.02
Number of pulsings (B)	0.04	0.02	0.06	0.02
Factor A × B	N. S.	0.03	N. S.	0.04

Table 8a. Ascorbic acid (mg/100 g) of acid lime cv. Balaji as Influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	49.81	49.86	49.92	49.98	47.18	47.22	47.46	48.64	45.49	45.62	45.93	46.42	43.73	44.33	44.74	45.33
8th day	42.17	42.32	42.64	42.86	41.32	41.86	41.91	42.03	39.32	39.62	40.64	40.86	38.24	38.59	38.71	39.22
12th day	-	-	-	-	39.35	40.55	-	-	38.47	38.95	39.28	39.85	-	-	38.68	39.73
16th day	-	-	-	-	-	-	-	-	-	36.61	38.56	-	-	-	-	-

Table 8b. Critical difference and standard error of ascorbic acid (mg/100 g) on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.07	0.03	0.14	0.05
Number of pulsings (B)	0.07	0.03	0.14	0.05
Factor A × B	0.15	0.05	0.28	0.10

Table 9a. Juice recovery (%) of acid lime cv. Balaji as influenced by ethylene concentrations and number of pulsings per 24 hrs at ambient temperature on 4th, 8th, 12th and 16th Day

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}
4th day	38.63	37.46	36.28	35.47	44.76	43.32	41.74	39.82	47.66	46.57	45.66	44.26	52.42	50.21	49.62	48.43
8th day	33.43	32.52	31.83	31.24	35.66	35.24	34.72	34.31	40.37	39.62	38.46	36.42	44.62	43.46	42.37	41.72
12th day	-	-	-	-	34.86	30.92	-	-	37.86	36.28	35.46	34.62	-	-	39.86	39.18
16th day	-	-	-	-	-	-	-	-	-	34.86	34.21	-	-	-	-	-

Table 9b. Critical difference and standard error of juice recovery (%) on 4th and 8th Day

Factors	4th day		8th day	
	CD (5%)	SE m±	CD (5%)	SE m±
Ethylene concentrations (A)	0.08	0.03	0.09	0.03
Number of pulsings (B)	0.08	0.03	0.09	0.03
Factor A × B	0.17	0.06	0.18	0.06

3.7 Juice Recovery (%)

The data pertaining to Juice recovery of Acid lime cv. Balaji at ambient temperature as influenced by ethylene concentrations and number of pulsings in Table 9. In present investigation, Juice recovery was decreased with the prolongation of storage period. The days of storage progressed the juice content increased up to ripe stage and declined thereafter during storage at ambient temperature. Juice recovery was decreased with the prolongation of storage period, this decrease might be due to the utilization of available organic acids at faster rate in respiration during ripening [11].

On 4th day among the ethylene concentrations, significantly highest % of juice was recovered with ethylene @ 20 ppm 50.17%; while, lowest with 5 ppm 36.96%. Among the number of pulsings, significantly highest % of juice was recovered with 6 pulsings in 24 hrs @ 4 hrs interval 45.87%; while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval 42.00%. On 8th day among the ethylene concentrations, significantly highest % of juice was recovered with ethylene @ 20 ppm 43.05%; followed by ethylene @ 15 ppm 38.72%; while, lowest with 5 ppm (32.25%). Among the number of pulsings, significantly highest % of juice was recovered with 6 pulsings in 24 hrs @ 4 hrs interval 38.52%; while, lowest with 1 pulsing in 24 hrs @ 24 hrs interval 35.93%.

Among the storage days 4th and 8th day interaction between ethylene concentration and number of pulsings were significantly differed. On 4th day significantly highest % of juice was recovered in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval 52.42%; while, lowest in 5ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval 35.47%. On 8th day significantly highest % of juice was recovered in 20 ppm ethylene with 6 pulsings in 24 hrs @ 4 hrs interval 44.62% while, lowest in 5 ppm ethylene with 1 pulsing in 24 hrs @ 24 hrs interval 31.24%. The mean values recorded in the of juice recovery Acid lime cv. Balaji fruits at 12th day and 16th day during storage tabulated at Table 9. A similar decreasing trend in respect of juice recovery was observed. It is evident from the data that as the days of storage progressed the juice content increased up to ripe stage and declined thereafter during storage at ambient temperature.

4. CONCLUSION

During post-harvest degreening of Acid lime cv. Balaji Physiological loss in Weight, Total Soluble Solids were increases. Peel thickness, fruit firmness, titratable acidity and ascorbic acid were decreases. The juice recovery increased up to ripe stage and declined thereafter during storage at ambient temperature. Finally, to conclude 15 ppm ethylene with 4 pulsings in 24 hours @ 6 hrs interval followed by 15 ppm ethylene with 2 pulsings in 24 hours @ 12 hrs interval can be recommended for Acid lime cv. Balaji for uniform degreening and storage up to sixteen days without affecting the quality parameters in normal room temperature.

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COMPETING INTERESTS

I (Pooja Yaddanapudi) declared that no competing interests exist.

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